Estimation of Nitrogen Content of Rice Plants and Protein Content of Brown Rice Using Ground-Based Hyperspectral Imagery

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Abstract

In this dissertation, the estimation of nitrogen content of rice plants and protein content of brown rice using ground-based hyperspectral imagery are investigated. To provide an overview of this research, a brief summary is given below.

Currently, rice is a staple food for more than 3 billion people in the world. Moreover, the world population is projected to grow to 7 to 9 billion by 2050 with demand for rice outstripping supply. However, inefficient agricultural activity, such as excessive nitrogen application for productivity gains, has and will continue to lead to degradation of the environment if nothing is done about it. Moreover, farmers are interested in maximizing yields and profits, while consumers are increasingly demanding high quality agricultural products. Meeting these sophisticated and diversified needs will demand more from agriculturalists than ever before. This is where the concept of precision agriculture has emerged to meet these sophisticated and diversified needs.

Management of crop variability is one component of precision agriculture. While minimizing crop spatial and temporal variability, it is also possible to optimize simultaneously both profitability and environmental conservation. For example, rice plant variability in crop traits that arise during growth can lead to quantitative and qualitative differences in harvested rice. Thus, it is important to develop techniques to visualize these preharvest crop traits so as to be able better control their variability to meet the above mentioned multiple demands. In the case of the rice crop, nitrogen content of rice plants at both panicle initiation and heading stage, and protein content just before harvest are key factors to control the variability of yield and quality (taste). Therefore, measurements of these factors using remote sensing with high resolution (1 × 1 mm) hyperspectral imaging were applied.

Nitrogen content (g/m^2) of rice plants is the product of dry mass per unit area and nitrogen concentration. It is difficult to explain all the variance of the nitrogen content using the spectral features of rice plants because they relate to concentration. For instance, variation in plant growth rates can result from temperature differences. Thus, a partial least squares regression (PLSR) model

that incorporates both the reflectance and growing degree-days (GDD) was constructed and evaluated. The results demonstrate that such an approach is adaptable enough to account for variations in inter-annual growing conditions for the prediction of rice nitrogen content at both thepanicle initiation and heading stage.

In order to improve the accuracy of rice protein content, estimation models were generated from the mean reflectance of five regions of interest (ROIs): the overall target area, non-canopy area (stems and soil), canopy area (leaves, yellow leaves, and ears), leaf area, and ear and yellow leaf area. These were compared to identify which part is most suitable for estimation in terms of accuracy. The results obtained show all models estimated rice protein content with high accuracy; no significant differences in estimation errors between the models was found with an analysis of variance (ANOVA). As a result, to minimize processing time, no segmentation of the image is recommended.

These results provide a method for estimating the nitrogen content of rice plants more precisely and refining the required specifications for remote sensing. As a consequence, these finer scaled more accurate determinations of crop nitrogen variation can be expected to improve crop management decisions, reduce input costs and environmental degradation associated with fertilizers, and inform more homogenous harvesting of crop traits such as taste, as well as determine the altitude needed for remote sensing platforms when imaging rice fields just before harvest.